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THE MISSISSIPPI RIVER FROM CAPE GIRARDEAU TO THE HEAD OF THE PASSES.*

BY

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PURPOSE.—The object of this paper is to review, in part, the Annual Reports of the Mississippi River Commission from 1883 to the present time, and to present certain problems therein discussed and others which arise from the study of the "Preliminary Maps of the Mississippi River from the mouth of the Ohio to the Head of the Passes," published by the Mississippi River Commission (1881–1885, 32 sheets; 1 inch equals 1 mile), and republished in 1894, with the results of the later survey entered in a marked overprint. The old survey in black and the new in red place in strong contrast the positions of the river over a period of thirteen years, and yield effective evidence of the changes in operation.

The publications of the Commission comprise many reports in the form of letters from engineers, detailed to different sections, and these are accompanied by much tabulated data and numerous maps. Some of these reports merely purport that a task assigned has been completed; others contain a great deal of valuable information. The lack of a complete index renders the publications unavailable for easy reference.

DEFINITIONS.—Before a discussion of the river is undertaken a clear understanding in regard to the use of certain terms is necessary. For the purposes of this article the following definitions of terms will be used:

The Mississippi River is conveniently divided into the Upper

* The author acknowledges the aid of Prof. W. M. Davis, under whose supervision this article was written.

Mississippi and the Lower Mississippi. The Lower Mississippi extends from St. Louis to the Gulf. The Upper Mississippi, like the Missouri and the Ohio, is treated as a tributary of the Lower Mississippi.

A meander (Fig. 1) is the well-formed curve of a river developed on a flood-plain. When two or more meanders occur on the same side of a stream a line drawn tangent to two adjacent curves represents the boundary of the meander belt on that side. The meander belt is the area between tangents on opposite sides of the stream. The tongue of land within the meander is the lobe. When the lobe lies between two meanders, and is connected with the mainland by a narrow passage, the narrow passage is the neck. The cutting action of the river narrows the neck until finally the river breaks through and forms a new channel or a cut-off. When a cut-off is established the former path of the river around the meander is deserted and the isolated meander becomes an oxbow lake or a lake. The average of the radii of the curves of any meander is the radius of curvature.

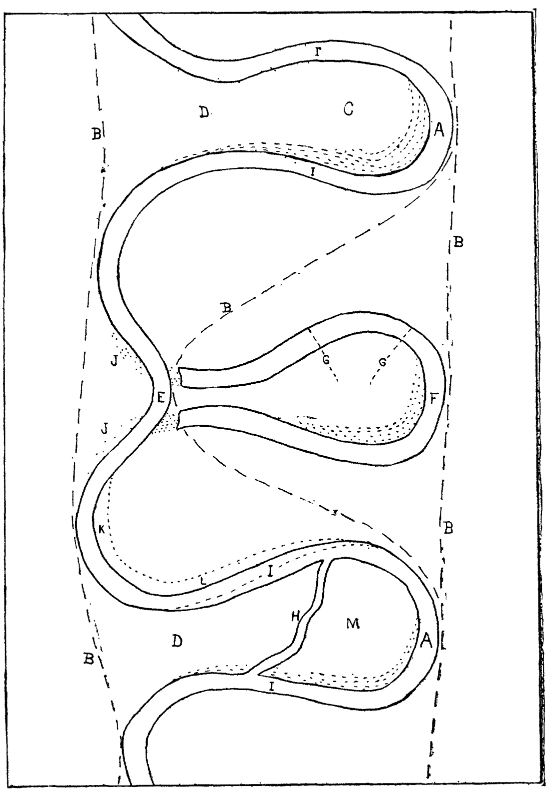


FIG. 1.
A =Meander or Bend. B =Boundary of Meander Belt, showing collapse of same after cut-off. C= Lobe, Spur or Point. D= Neck. E= Cut-off. F= Ox-bow Lake or Lake. G= Radius of Curves. H= Chutes. I= Crossings. J= Fill. K= Toe-cap flood-plain. L= Scroll flood-plain. M= Island.

By the slope of the river the inclination of the water surface may be understood. The sectional area is a cross section, perpendicular

to the current, and is expressed in square feet. The discharge is the volume of water passing towards the sea in a given unit of time. The stage of a river means the height of water surface at a given point above or below a fixed plane of reference. The plane is ordinarily selected at the level of lowest-known water. The stage, therefore, indicates the danger of overflow in adjacent portions of the river. Chutes are the narrow passages of water between an island and the mainland. Where the channel of fastest flow crosses the river in passing from the outer bank of one meander to the outer bank of the next a crossing is established. Islands retain their name even after the chutes have been filled. A crevasse is a break in the levee system through which a swollen stream finds relief by discharge.

THE PLACE OF THE MISSISSIPPI IN RIVER CLASSIFICATION.—As a whole, the Mississippi River system is complex, and because of its heterogeneity it cannot be described in simple terms. That portion, however, which interests us runs, for the most part, on a coastal plain, and the river is consequent on the slope of the plain. The uplift of this coastal plain has extended the main trunk of the Mississippi and joined with the system the Arkansas, Red, and White Rivers as tributaries. There is strong evidence (Griswold, '95, 474) that a barrier to the southern drainage formerly existed at the Ozark Mountains, and that an interior sea in the west received the drainage north of these mountains. A warping of the barrier or a capture by the stream, consequent on the coastal plain, or both, turned the Upper Mississippi drainage southward. In this way the simple consequent river, engrafting the rivers now its southern tributaries and capturing the northern drainage, became the present complicated stream. The present sinking of the region about the mouth of the river tends to embay it, but the load of sediment which the Mississippi deposits builds out and up as fast as the land goes down and prevents the drowning. In any consideration of the age of the Mississippi it is again necessary to deal with the river in its parts. The tributaries of the river are in their youth. The main trunk of the river, the Lower Mississippi, has reached maturity, and is fairly well advanced in this stage.

NUMERICAL DATA.— The following is tabulated from various sources:

Distance from Cape Girardeau to Gulf, by water......	1,700 miles
Distance from Cape Girardeau to Gulf, straight line..	600 miles
Entire area drained by the river..........	1,240,000 square miles

(Equivalent to one-third of the United States.)

Average annual precipitation over basin............ 29.8 inches
Annual discharge of water........... 785,190,000,000 cubic yards
Ratio of discharge to rainfall............................ 0.25
Total amount of sediment, yearly.............. 406,250,000 tons
Ratio of sediment to water by weight................... 1 : 3575
Average depth removed over drainage area......... .00223 inches
Annual discharge of sediment... .... 7,459,267,200 cubic feet
Solid matter in solution, yearly................ 112,832,171 tons
Height of high water above Gulf at Cairo............... 322 feet
Height of low water above Gulf at Cairo................ 271 feet

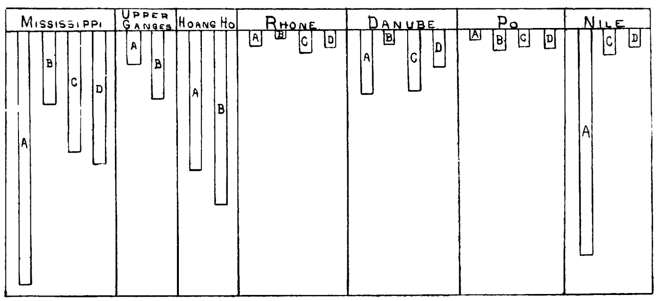


Fig. 2.

Drainage Area and Discharge of the Mississippi River compared with the same features of other large streams:

A. Drainage area in sq miles 1/16 in. = 30,000 miles.
B. Annual discharge in cu. ft. 1/16 in. = 600,000,000 cu. ft. (Geikie).
C. Annual discharge in cu. ft. per sec. 1/16 in. = 30,000 cu. ft. (Babb).
D. Annual discharge in tons 1/16 in. = 19,000,000 tons.

The slope of the river is a varying quantity and diminishes as the Gulf is approached. A table of slope is sufficiently instructive to be included (Humphreys and Abbot, '61, 107).

STATION.	DISTANCE.	HIGH WATER.	LOW WATER.	DIFFERENCE.	RESULTING FALL PER MILE.		
					TO	HIGH FEET.	LOW FEET.
	Mi.	Ft.	Ft.	Ft.			
Head of Passes	0	2.8	0.5	2.3	....	....	....
Fort St. Philip	20	5.1	0.6	4.5	Head of Passes	0.115	0.005
Carrollton	104	15.3	0.9	14.4	Fort St. Philip	0.121	0.004
Donaldsonville	176	25.8	1.5	24.3	Carrollton	0.146	0.008
Baton Rouge	228	33.9	2 8	31.1	Donaldsonville	0.156	0.025
Red River Landing	299	49.5	5.2	44.3	Baton Rouge	0.222	0.034
Natchez	361	66	15	51	Red River Landing	0.266	0.158
Vicksburg	470	..	..	49	....	....	....
Gaines Landing	630	149	..	..	Natchez	0.309	....
Napoleon	672	..	..	50	....	....	....
Memphis	855	221	181	40	Gaines Landing	0.320	....
Columbus	1059	310	263	47	Memphis	0.436	0.402
Cairo	1080	322	271	51	Columbus	0.571	0.382
St. Louis	1253	408	371	37	Cairo	0.497	0.578

The slope of the river from St. Louis to Cairo is greater at low water than at high water. The explanation of this singular feature lies in the large volume of water poured into the Mississippi by the Ohio during a flood in this tributary. The discharge of the Ohio increases the slope south of Cairo and at the same time decreases the slope north of Cairo. Similar effects, though less well marked, may be observed from the floods of the other tributaries.

The velocity of the river is largely a function of the slope and the resistance. The Mississippi has a velocity ranging from 1 to 6 miles per hour. An average velocity in the lower part may be roughly stated as 4.2 feet per second (equivalent to 2.86 miles per hour). In any sectional area of a river the velocity of the water varies in different parts. The area of greatest velocity in a symmetrical cross section will not be near the bottom nor along the banks, where inequalities of floor or wall hinder the flow; nor at the surface, where atmospheric resistance is encountered. It will be somewhere below the surface, and probably nearer the top than the bottom of the sectional area. It has been determined by Humphreys and Abbot ('61, 302 *et seq.*) that the mid-depth velocity of any vertical plane is not far from the mean velocity. The ratio between the mid-depth velocity and the mean velocity increases slightly with the size of the stream. The mean of several mid-depth velocities taken at equidistant stations, the banks being considered two of them, will approximate very closely the mean velocity of the stream.

General Shape.—The river courses through an alluvial plain. The river's position has formed four smaller basins in the large basin of the Lower Mississippi—the St. Francis, extending from Cape Girardeau to Helena on the west of the trunk stream; the Yazoo, from Memphis to Vicksburg on the east; the Tensas, from New Madrid to the Red River on the west; and the Red River Basin continuing on the same side to the Gulf. The head of the alluvial plain is at Cape Girardeau, where the higher land of the upper river ceases. From Cape Girardeau to the Gulf the river touches the high lands on the west in two points only—New Madrid, Mo., and Helena, Ark.; while on the east at numerous points—Columbus and Hickman, Ky., the Chickasaw Bluffs, and various localities between Vicksburg and Baton Rouge.

A cross section of the flood-plain of the river (Fig. 3) shows the normal features. The mean fall of the back slope of the flood-plain from the river averages about 7 feet in the first mile—the

minimum is about 4 feet in the first mile at Cairo, and the maximum 13 feet near Baton Rouge. In general, then, the amount of fall in the back slope of the flood-plain increases towards the mouth of the river.

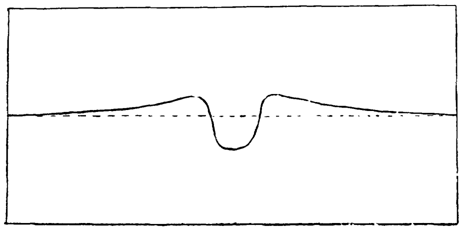


FIG. 3.

CROSS-SECTION OF FLOOD-PLAIN (VERTICALLY EXAGGERATED). DOTTED LINE REPRESENTS THE WATER LINE.

The river exhibits the general behaviour of meandering streams. Against the concave banks the river presses with force, and erosion is rapid. In addition, as the line of fastest current is delivered to the down valley side of every crossing, there results from these causes an increase in the radius of curvature of the meanders and the down-stream progress of them. This increase in the radius of curvature will account for many lakes with a radius of curvature larger than any existing meander. The lakes represent the largest curve that was attained in the meander stage. The increase of the curve is reflected in the outbuilding of the end of the lobe (toe-tap flood-plains) and the down-valley movement systematically develops the lobe on the down-river side (flood-plain scrolls, Fig. 1). When a cut-off occurs in the process of bank erosion the meander belt collapses (Fig. 1) to a minimum, and subsequent erosion tends to increase its width until another cut-off occurs.

TRIBUTARIES.—The tributaries of the Lower Mississippi are of three types:

(*a*) Rivers which flow directly across the flood-plain into the Mississippi. The Arkansas, White, and Red Rivers belong to this class.

(*b*) Rivers which run parallel to the main river for some distance before entering it. The St. Francis, Yazoo, Tensas, and Atchafalaya Rivers are the representatives of this type.

(*c*) Rivers which, because of the position of the Mississippi near the high lands, enter the trunk stream directly, crossing little or no part of the flood-plain. Many of the smaller tributaries on the east between Vicksburg and Baton Rouge belong here

A tributary, in order to belong with the first of these, must be strong enough to overcome the building of the flood-plain by the trunk stream. Many streams cannot do this, and these course down the valley in the depression of the flood-plain until the greater bar-

rier of the high land is encountered. Thus the St. Francis enters the Mississippi when it is a question between the higher lands at Helena and the flood-plain. The Yazoo is forced to enter under similar conditions at Vicksburg, where the Mississippi, after recrossing the basin, touches the higher land again on the east. The Tensas is cornered by the Red River. The Atchafalaya flows into the Gulf of Mexico, and does not enter the Mississippi at all.

CUTTING OF BANKS —The deviation from a straight course by a river has been variously explained. The analogy with a fat man running down hill has been admitted in testimony (Mississippi River Floods, '98, 224). The man, it is maintained, knows that on account of the momentum it is unsafe to go down directly, so he zigzags down the slope, and the river unconsciously follows the conscious effort of the heavy-weight. In more usual terms Ferguson writes ('63, 322):

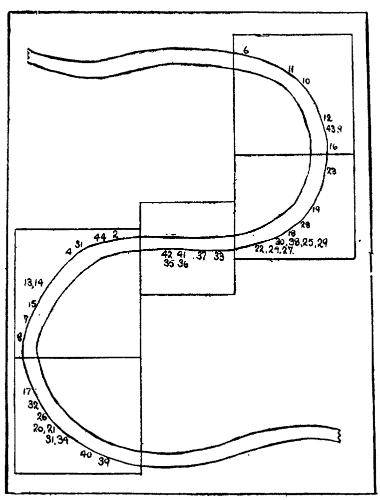
> A river is a body of water in unstable equilibrium, whose normal condition is that of motion down an inclined plane; and if we could abstract all the natural conditions of inequality of surface or of soil, it would flow continuously in a straight line ; but any obstruction or inequality whatever necessarily induces an oscillation, and the action being continuous, the effects are cumulative, as those in a pendulum are discumulative ; and the oscillation goes on increasing until it reaches the mean between the force of gravity tending to draw it in a straight line, and the force due to the obstruction tending to give it a direction at right angles to the former. If this be so it will immediately be perceived that the extent or radius of the curves will be directly proportional to the slope of the bed of the river.

A general law may be stated thus: A river on a flood-plain will deviate from a straight line because of obstructions. These obstructions include variations in the resistancy of the banks and the effects of the earth's rotation. Inequalities of surface or of soil alone will not suffice as an explanation. After a cut-off the river is comparatively straight along a limited portion of its course. What irregularities remain are gentle in curvature. The scour of the banks will begin at once to shape the curve into the true meander by decreasing the radius of curvature. When the meander stage is reached the increasing of the radius of curvature begins, so that the radius of the curve at the birth of the meander is the least, and at the time of the cut-off is the largest, curve that that meander attained. If this is true, while we may find some lakes with a smaller radius of curvature than some existing meanders, in the main the lakes will have a larger average radius. Eighteen lakes yield an average radius of curvature of 12,000 feet, and 13 meanders—taken consecutively—7,700 feet.

The rate and place of cutting may be obtained from a study of the river landings on the maps of the two surveys (Fig. 4). The landings occur along the steep banks of the river, where undercutting is rapid, and a steamer may thus approach near enough to the bank to allow a gang-plank to connect it with the shore. In 15 landings, 5 were found at the end of meanders and 10 on the up-river side of lobes. Every one of these had been moved between 1881 and 1894 from 1,000 to 5,000 feet. In each case the movement was away from the river, showing bank cutting. The 5 indicated the widening of the meander belt and the 10 the down-stream

LANDINGS.

1 Craigs.
2 Harwood.
3 Good Luck.
4 Linwood.
5 Eutaw.
6 Jenkins.
7 Gaines.
8 *Cypress.*
9 Stop.
10 Easton.
11 Glenora.
12 *Riverton*,
13 Bellevue.
14 Vancluse.
15 Monterey.
16 *Barnes.*
17 Luna.
18 *Longwood.*
19 Mound.
20 Sunnyside.
21 *Chicora.*
22 Tarpley.



LANDINGS.

23 *Bolivar.*
24 Glencoe.
25 *Buckridge.*
26 *Pilcher.*
27 Kentucky.
28 Carolina.
29 *Delohne.*
30 Utopia.
31 Curriola.
32 *Grand Lake.*
33 Home.
34 *Upper Leland.*
35 Warfield
36 Lake Washington.
37 Carter's Point.
38 Holly Ridge.
39 Chicot.
40 Point Comfort.
41 *Franklin.*
42 *Cat Fish.*
43 *Leota.*
44 *Sterling.*

FIG 4.

DISTRIBUTION OF LANDINGS ON MEANDERS FROM ROSEDALE TO SKIPWITH, SHEETS 13, 14, 15, 1900 SURVEY.

Landings in italics displaced by caving banks 1,000 feet or more.

progress of the meander. The average rate of movement of the 15 landings was 150 feet per year; the average annual rate of 27 localities tabulated in the Reports ('82, 162) yielded 100 feet. Marengo Bend (Fig. 5), near Natchez, illustrates the unstable conditions of the banks.

A further feature is shown by the 18 lakes. Seven of these are on the east, and have an average radius of curvature of 10,000 feet; and 11 are on the west, with an average radius of curvature of 13,000 feet. This has been explained by Ferrel's law, that a stream under the influence of the earth's rotation always tends to wear its right bank in the Northern Hemisphere. Gilbert ('84, 427) states

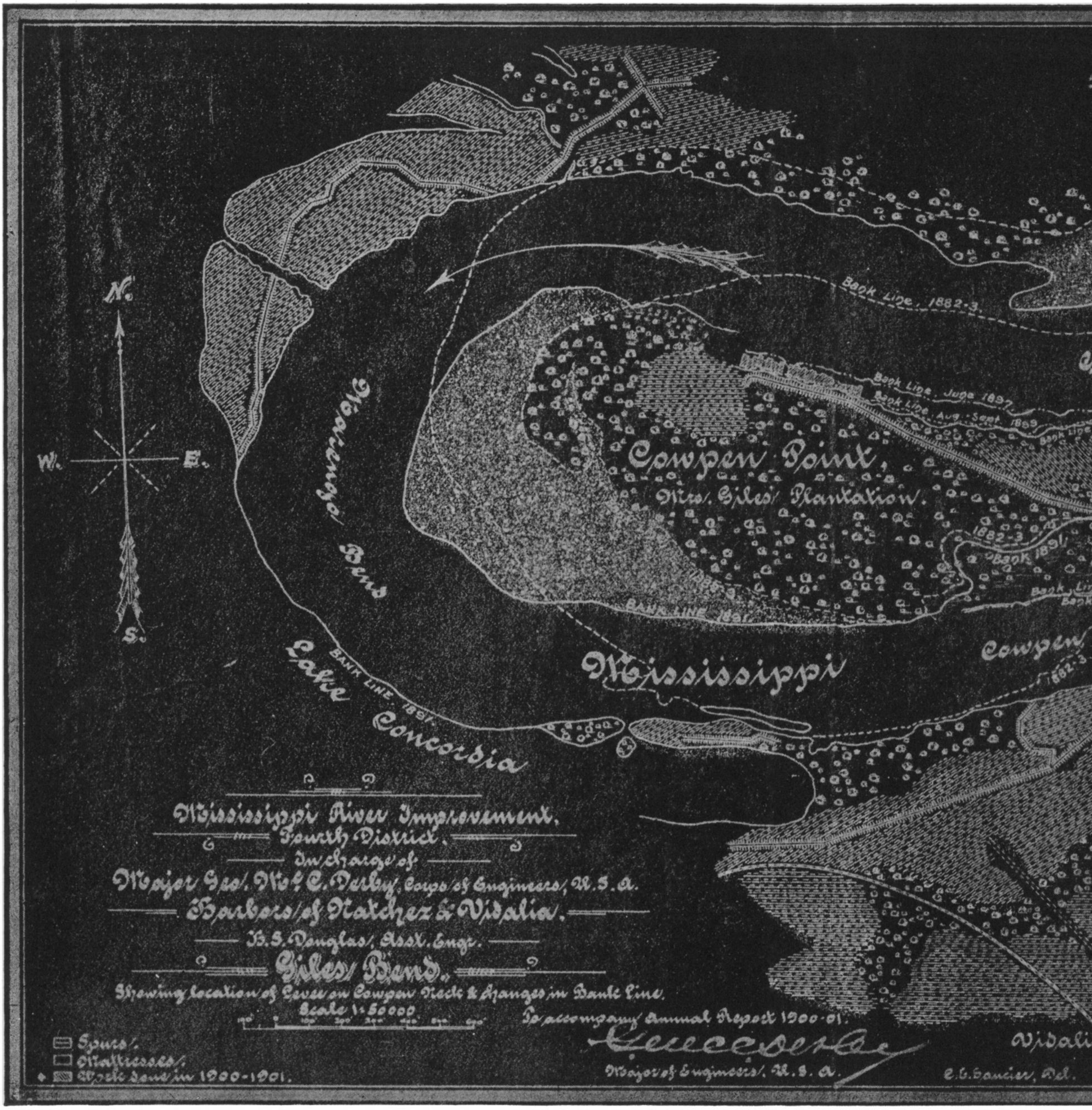

N.
W.
E.
S.
Cowpen Point.
Mrs. Giles' Plantation.
Mississippi
Lake Concordia
Bank Line 1882-3.
Bank Line June 1897.
Bank Line Aug.-Sept. 1899.
Bank Line 1891.
Mississippi River Improvement.
Fourth District.
In charge of
Major Geo. McC. Derby, Corps of Engineers, U. S. A.
Harbors of Natchez & Vidalia.
B. S. Douglas, Asst. Engr.
Giles Bend.
Showing location of Levee on Cowpen Neck & changes in Bank Line.
Scale 1:50000
To accompany Annual Report 1900-01.
Major of Engineers, U. S. A.
Spurs.
Mattresses.
Work done in 1900-1901.

FIG. 5.

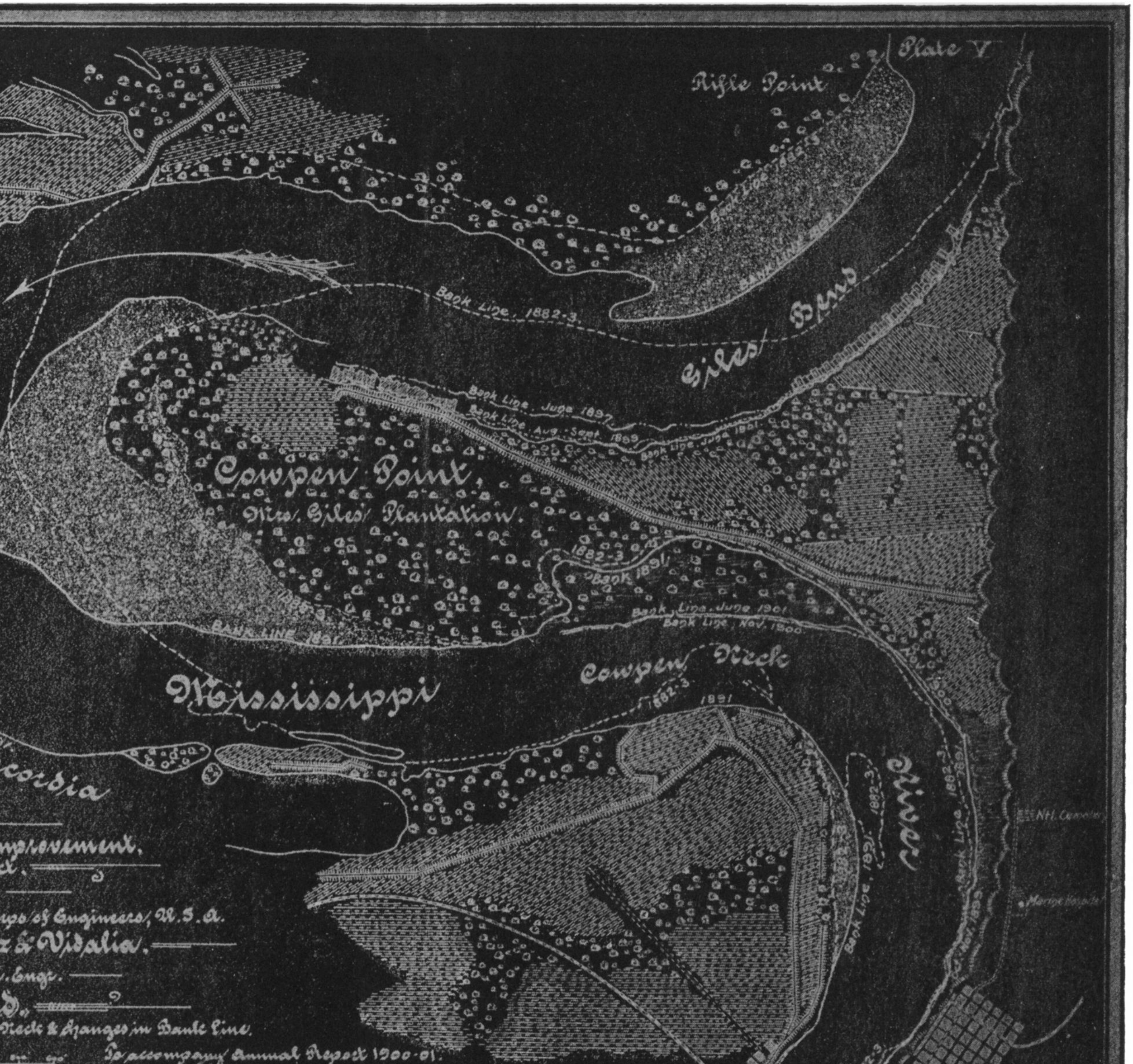


Plate V
Rifle Point
Giles Bend
Cowpen Point
Mrs. Giles Plantation.
Mississippi
Cowpen Neck
River
Vidalia
Natchez
To accompany Annual Report 1900-01.
Major of Engineers, U. S. A.

Fig. 5.

that the selective tendency in the case of the Mississippi is nearly 9% greater than towards the left bank. In the Connecticut River, Emerson ('98, 734) finds 7 cut-off oxbows on the west—right bank—and none on the east. If the deviation of Ferrel's law was alone operative it would be necessary to expect more lakes on the left (Fig. 6). At A the law induces a cut-off and at B opposes one. Other things being equal, A will cut through before B, and the lake will occur on the left bank. No satisfying explanation of the arrangement of lakes has been found. A stream in passing a bend is ponded until the resistance to the change of direction is overcome. The ponding will be greater in the sharper bend. It is likely that the sharper meanders, generally the east ones, in times of flood, oppose the passage of the volume of water sufficiently to allow a wash-over at the neck. This wash-over is a considerable factor in a cut-off, and, as the sharper bends are the east ones, the tendency of the river is to hasten a western oxbow lake.

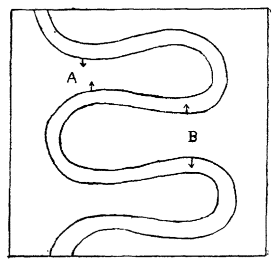


Fig. 6.

Deposits.—The material corraded from the banks of the river may be carried down to add to the enormous pile that forms the delta of the Mississippi, or it may find a temporary resting-place over the broad flood-plain borne by some flood, or some of the minor depositions may be formed by it within the banks of the river. Many of the islands so numerous in the river have been formed in the quieter portions of the stream, and other islands are in the process of growth. Starting as a sand bar, driftwood finds anchorage upon it, and deposition is increased. A willow growth further aids its building during high water. Later, the chutes are filled and the island is joined to the mainland, to be at a later time, probably, destroyed by the river. Opposite the position of rapid cutting is a portion of the river flowing under a weakening activity, and consequently depositing. Here are formed the toe-taps and the scroll flood-plains which appear so frequently on the end and down-river side of the lobes. This work is in more active progress in the upper than the lower parts of the river, where it has comparatively ceased.

CUT-OFFS.—The following list comprises most of the recorded cut-offs:

DATE.	NAME.	LENGTH.	
1722	Fausse River—Bunches	13 miles.	
1821	Needham's............	11 miles.	
1831	Shreve's..............	18 miles.	Made by U. S. Engineers.
1848	Raccourci	21 miles.	Made by State of La.
1848	Horseshoe............	8 miles.	
1858	American Bend........	10 miles.	
1863	Napoleon.............		
1866	Terrapin Neck........	14 miles.	
1867	Palmyra Bend.........	25 miles.	
1874	Council Bend..........		
1876	Centennial............		
1876	City of Vicksburg.....	10 miles.	
1876	Devil's Elbow.........	25 miles.	
1884	Waterproof...........	12.5 miles.	

The rapidity with which a cut-off is made when no human agency hinders may be illustrated by quoting from Humphreys and Abbot ('61, 97):

They (cut-offs) are believed to be likely to occur before many years at the neck above Napoleon, which was only 1,400 feet across in 1858, and caving badly; at the neck between Islands 98 and 101 (Terrapin), then reported to be 1,200 feet across and caving badly above; at the neck between Islands 105 and 110 (Palmyra), said to have been 10,000 feet across in 1808, and to be only 2,700 feet now (1858), and caving above; at the neck, between Islands 113 and 114 (Waterproof), caving badly above, and reported in 1858 to be only 2,400 feet across. There are other narrow necks—as those near Vicksburg and Grand Gulf, for instance—but there seems to be no reason to anticipate the early occurrence of cut-offs at them.

Five years later the river cut across at Napoleon; eight years later at Terrapin Neck; nine years later at Palmyra, and twenty-three years later at Waterproof. The Vicksburg cut-off occurred in eighteen years.

Mr. James (Reports, '82, 235) describes the occurrence of a cut-off:

The event which has had more to do with the alteration of the level, and consequently of the general appearance, than any other phenomenon, not excepting the earthquakes of the early part of the century, was the Devil's Elbow cut-off in 1876. The writer hereof was at Shawnee Village, 10 to 12 miles away, and he distinctly felt the shock, and heard the roar of the mighty mass of water as the river cut its way through the narrow neck of land that had hitherto restrained it, and plunged at one leap down the descent which it had formerly crawled 25 miles to make.

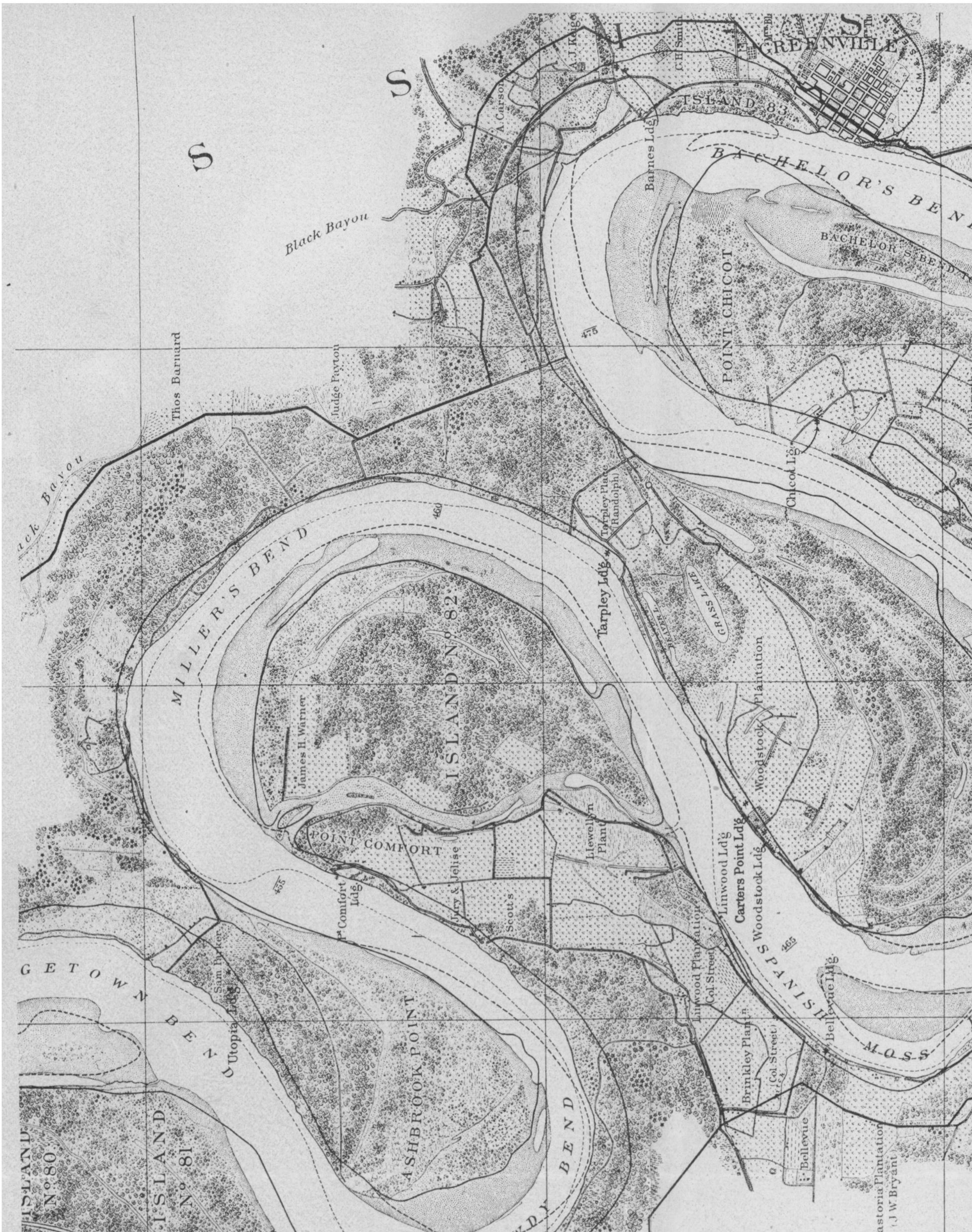


FIG. 8.

1881 SURVEY. 1894 SURVEY IS ENTERED BY CONTINUOUS LINES. DOTTED LINES INDICATE SHOALING. HEAVY LINES REPRESENT LEVE

FIG. 8.

RED BY CONTINUOUS LINES. DOTTED LINES INDICATE SHOALING. HEAVY LINES REPRESENT LEVERS. SCALE 1 INCH=6,700 APPROX.

FIG. 7.

MAP OF COLES POINT, 1881 SURVEY. 1894 SURVEY IS ENTERED BY CONTINUOUS LINES. DOTTED LINES INDICATE SHOALING. HEAVY LINES REPRESENT LEVEES. SCALE 1 INCH=7000 FT. APPROX.

CHANGES CONSEQUENT ON CUT-OFFS.—Such have been the conditions following a cut-off that the engineers, almost in unison, cry out against their occurrence, and urge that all measures be used to prevent them. In the cut-off just described the immediate result was to check the rise in the river for 100 miles up stream. At Osceola, about 50 miles above, the river fell 22 inches in a few hours on a rising stream. Golden's Lake and the bottoms between it and Frenchmen's Bayou were drained. Young's and Carson's Lakes were lowered 4 to 6 feet. The water-level below a cut-off is raised. The increase of velocity, because of an increase of slope, increases the caving in the banks, both above and below its site. Waterproof cut-off occurred between the 1881 and the 1894 survey. The river before and after the occurrence is then open to comparison. Inspection of the results on the river banks (Fig. 7) shows that a new system of cutting and depositing is begun after a cut-off. The places of deposition may be termed "fills," and they are most highly developed in the bends leading to and from the deserted meander. Up and down stream from these on alternate sides of the stream they occur in diminishing prominence until they are lost in a more powerful action. Between the fills cutting occurs, and the river at once begins to regain its lost length.

Starling ('97, 2–4) disapproves of cut-offs because of the resulting instability. He states that in sixteen years after the Vicksburg cut-off, which shortened the river 6.5 miles, in a hundred miles the river had regained 4 miles:

In 1825, from the Ohio to the mouth, the river was 954 miles; in 1882, 963 miles. In 1884 occurred the Waterproof cut-off, which shortened the river 12.5 miles. The distance in 1897 is about the same as in 1825. In seventy-two years, however, fourteen cut-offs have occurred, with a shortening of at least 160 miles.

The Greenville curves open both sides of the question. A cut-off is threatening at Ashbrook Point (Fig. 8). The neck at this point was, in 1883, over 4,000 feet wide; it is now less than 2,500 feet. Should a cut-off occur here others would be precipitated. Point Chicot, a short distance below, has a neck of only 3,000 feet. Greenville, on Bachelor's Bend, is even now struggling to maintain its position. The dike is standing to-day where was the centre of the town. By a system of leap-frog movements—the owners on the river bank building in the outskirts as fast as they are driven out by the cutting stream—the town has been kept on the alert, and its constant danger has not prevented its growth. Its population in 1880 was 2,191; in 1890, 6,658; and in 1900, 7,642. To protect this town the sum of $799,271.24 had been expended up to 1899,

and this does not include $42,277.10 contributed by the city itself in 1887; and the danger does not decrease. The Ashbrook Point cut-off will increase the cutting at Greenville and be a new source of alarm to the town, or a cut-off will be precipitated at Point Chicôt neck, and Greenville be left two miles from the river. It is for the interest of Greenville to deplore both these events and to prevent further cutting by large outlays. Yet the place is doomed, and a sum of money, which probably exceeds the valuation of the town, has been expended in a hopeless fight. It is better to continue the outlay, in so uniting with the efforts of the river as to secure a gently curving channel, along the banks of which protection from caving may be relatively a simple task.

The engineer foresees in a cut-off at Ashbrook Point cut-offs in the two bends immediately below, which altogether would shorten the river at least 30 miles. The changes in the river banks would be enormous in extent and would continue for many years, or until the river had regained its length. Thus it has been regarded by the engineers as of prime importance that the Ashbrook cut-off should not occur. The plea of the merchant that the destruction or isolation of Greenville will be felt beyond the limits of the city itself, since an important commercial centre will then be lost or lose its geographical advantage, is not a valid argument for the national expenditure of large sums in order to delay an evil, nor is it an excuse for rearing a city in the face of such an event.

Cowpen Neck (Fig. 5) threatens a cut-off, and this occurrence will probably deposit sand along the Natchez front and destroy the harbour.

BOTTOM.—The bed of the river oscillates about a certain well-defined average condition, and is in a state of constant motion. Sand bars are deposited under the action of changing velocities, so that the bottom is a series of pools and shoals. In a constant velocity and volume of the stream a tendency towards the average condition results, and, as both these factors change, the departure from the average becomes marked. The rapidity of change intensifies the departure from the average condition, as the duration of constant flow aids the approach to the average.

The transportation of sediment along the bottom has been shown (Reports, '82, 88) to be carried on in a series of ridges of irregular shape, transverse to current direction. These ridges or waves attain their maximum size and speed at high water, and at the same time they approach a regularity of movement down stream. A rapid

increase in velocity or a corresponding decrease obliterates the waves by increasing the scour or forming shoals, but they reappear again as the current approaches uniformity. The advance of the wave and the transportation of sediment are carried on by the material rolling up on the up-river side of the ridge and depositing on the down-river side. A great deal of the load of a stream is transported in this way near the bottom.

(*To be continued.*)